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THE BWR CORE SIMULATOR COSIMA WITH 2 GROUP NODAL FLUX EXPANSION AND CONTROL ROD HISTORY

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Abstract

The boiling water simulator NOTAM has been modified and improved in several aspects:

- The "1 1/2" energy group TRILUX nodal flux solution method has been exchanged with a 2 group nodal expansion method.
- Control rod "history" has been introduced.
- Precalculated instrument factors have been introduced.

The paper describes these improvements, which were considered sufficiently large to justify a new name to the programme: COSIMA.

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1. INTRODUCTION

At the Nordic Reactor Physics Conference in Helsinki in 1987 the programme complex LEWARD/NOTAM was presented (1), as well as calculations on the Quad Cities reactor for verification of the programme (2).

It was found that the agreement between calculations and experiments was quite good in the beginning of the core life, but became increasingly poorer as power production increased.

A number of unsatisfactory programmatic procedures were identified, the three most serious being:

a) The "1 1/2" energy group TRILUX nodal flux solution method used in NOTAM employs some empirical coupling constants, which are dependent on the problem in question.

b) The way in which control rod history was taken into acount was very crude, as there was only two sets of cross sections:

   One set where the control rod was in and had been so for the whole preceding burnup time, and another set, where the control rod was out and had been out the whole time.

c) The measure of the power in four adjacent channels was taken as s simple average of the channels.

The present paper describes the solutions engaged to overcome these three problems. The resulting programme was sufficiently changed to justify considering it a new programme. It has been named COSIMA.

2. EXCHANGE OF POLKA (TRILUX) WITH THE NEM

A Ph.D. work performed some years ago at Risø (3) produced a true multigroup nodal program based on the Nodal Expansion Method, NEM.

This program was properly modified to be compatible with the rest of NOTAM and thus substitute the TRILUX routine (POLKA).

The NEM is "self-contained", i.e. it does not depend on any dubious constants, but requires only regular multigroup data as diffusion coefficients,scattering matrices, fission cross sections etc. The method allows the use of cross sections modified with the socalled "discontinuity" factors, which to some extent will compensate for using homogeneous cross sections in large nodes containing strong inhomogeneities.

Discontinuity factors were used with the TRILUX method as well, but it was never analyzed whether that was allowed.

3. INTRODUCTION OF "CONTROL ROD HISTORY"

Previously, the cross sections used in the BWR simulator, NOTAM, had been calculated by the LEWARD programme in the way that one set was produced assuming a control rod inserted during the whole burnup history, and another set was produced assuming no control rod inserted at any time.

The burnup distribution within the assembly is, of course, dependent on the time in which the control rod has been in, and so are the nuclear properties of the assembly. An exact simulation of the CR history is not possible unless the assembly burnup calculations are made currently for each node during the overall simulation of the core performance.

This seems presently to require quite prohibitive calculational efforts, and thus some approximative method had to be developed.

The method chosen assumes that as to the dependence of burn up, the nuclear properties of an assembly depend on:

1) The total burnup
2) The part of the burnup in which the control rod has been inserted

but not on the detailed time variation of the control rod movements.

The principles are illustrated in Fig. 1, where the actual control rod movements are shown at the bottom, and the assumed distribution of burnup with and without control rod indicated in the diagram.

It is seen that burnup-wise the control rod presence is pushed from the actual time to the beginning of life of the fuel.

For most of the nuclear parameters there is quite a dramatic variation to be seen, when the control rod history is taken into account. Being the most integral quantity, k_{inf} is shown in Fig. 2 for a Quad Cities assembly with 3 gadolinium rods.

The effect is most pronounced at low burnup, but is clearly seen also at higher burnups.

In Fig. 3 the k_{inf} for a gadoliniumfree assembly is shown. Although the dependence on control rod history is clearly seen, the effect is much less pronounced than in the case with gadolinium.

4. INTRODUCTION OF "INSTRUMENT FACTORS"

As measure of the power in the 4 assemblies surrounding the TIP's in a BWR, a simple average of the powers of the 4 assemblies was used in NOTAM.

Especially when a control rod is present, the flux at the TIP position may be quite different from the average.

The flux distribution is known in great detail in the assembly calculations, and thus it is an obvious and cheap improvement to take calculated reaction rates in the TIP-positions from the assembly calculations and treat them in exactly the same way as the cross sections, i.e. interpolate in burnup, void, control rod history etc.

3 different reaction rates are calculated corresponding to fission chambers, gamma thermometers and gamma ionization chambers.

In Fig. 4 an example of the range of variation which such an instrument factor has with respect to burnup, control rod presence and control rod history is shown.

5. CONCLUSION

A number of badly modelled phenomena have been identified in the BWR core simulator programme NOTAM.

3 of them and the improvements designed for them have been described in the present paper.

It is shown that the changes in the cross sections due to control rod history are large enough to warrant considerable changes in the over-all reactivity and power distribution.

Also, the introduction of instrument factors will change the comparisons with TIP-measurements, especially where a control rod is present in one or more of the 4 channels belonging to a TIP.

The verification calculations planned on Quad Cities have not yet been performed, because the B7800 computer on which the programmes were developed, has been taken out of operation recently, and the transfer of the programmes to the VAX8700 is not completed.

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(3) CHRISTENSEN, B. (1985). Three-dimensional Static and Dynamic Reactor Calculations by the Nodal Expansion Method. Risø-R-496.

FIGURE 1.

CONTROL ROD HISTORY APPROXIMATION

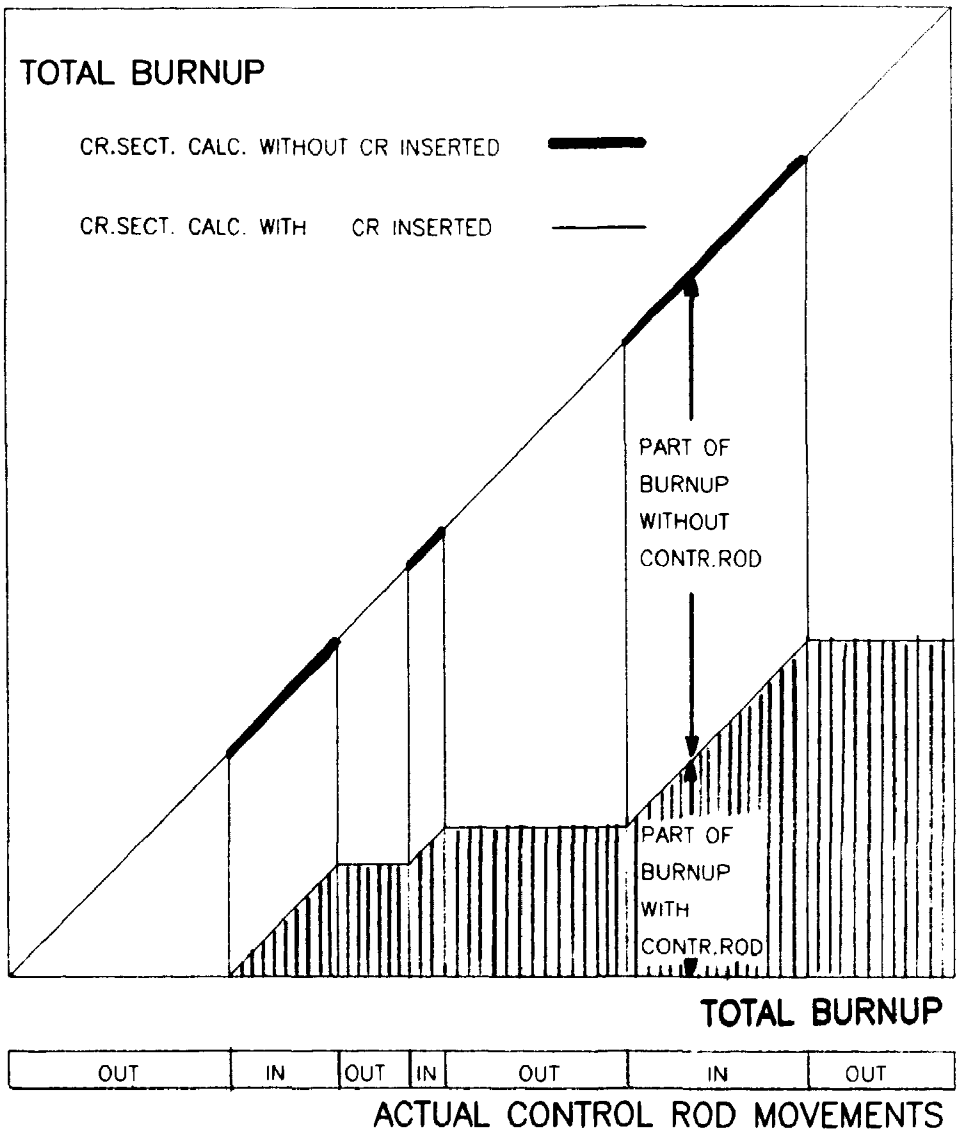


FIGURE 2.

KINF AS FUNCTION OF BURNUP, WITH AND WITHOUT CONTROL

PARAMETER IS THE BURNUP, WHICH HAS TAKEN PLACE WITH THE CONTROL ROD IN

FUEL ASSEMBLY: QUAD CITIES, 3 GD PINS, 50% VOID

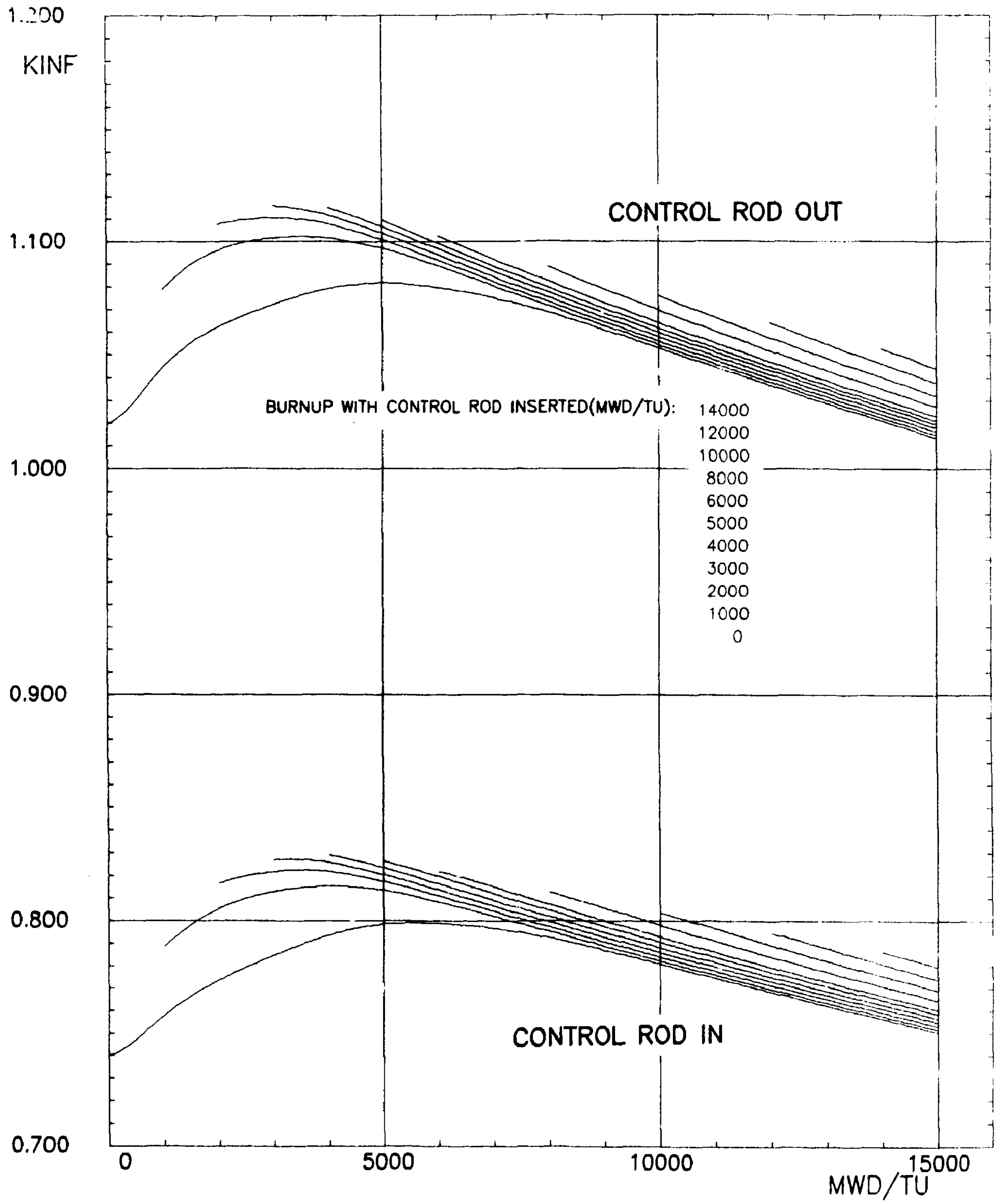


FIGURE 3.

KINF AS FUNCTION OF BURNUP, WITH AND WITHOUT CONTROL

PARAMETER IS THE BURNUP, WHICH HAS TAKEN PLACE WITH THE CONTROL ROD IN

FUEL ASSEMBLY: QUAD CITIES,NO GD PINS, 50% VOID

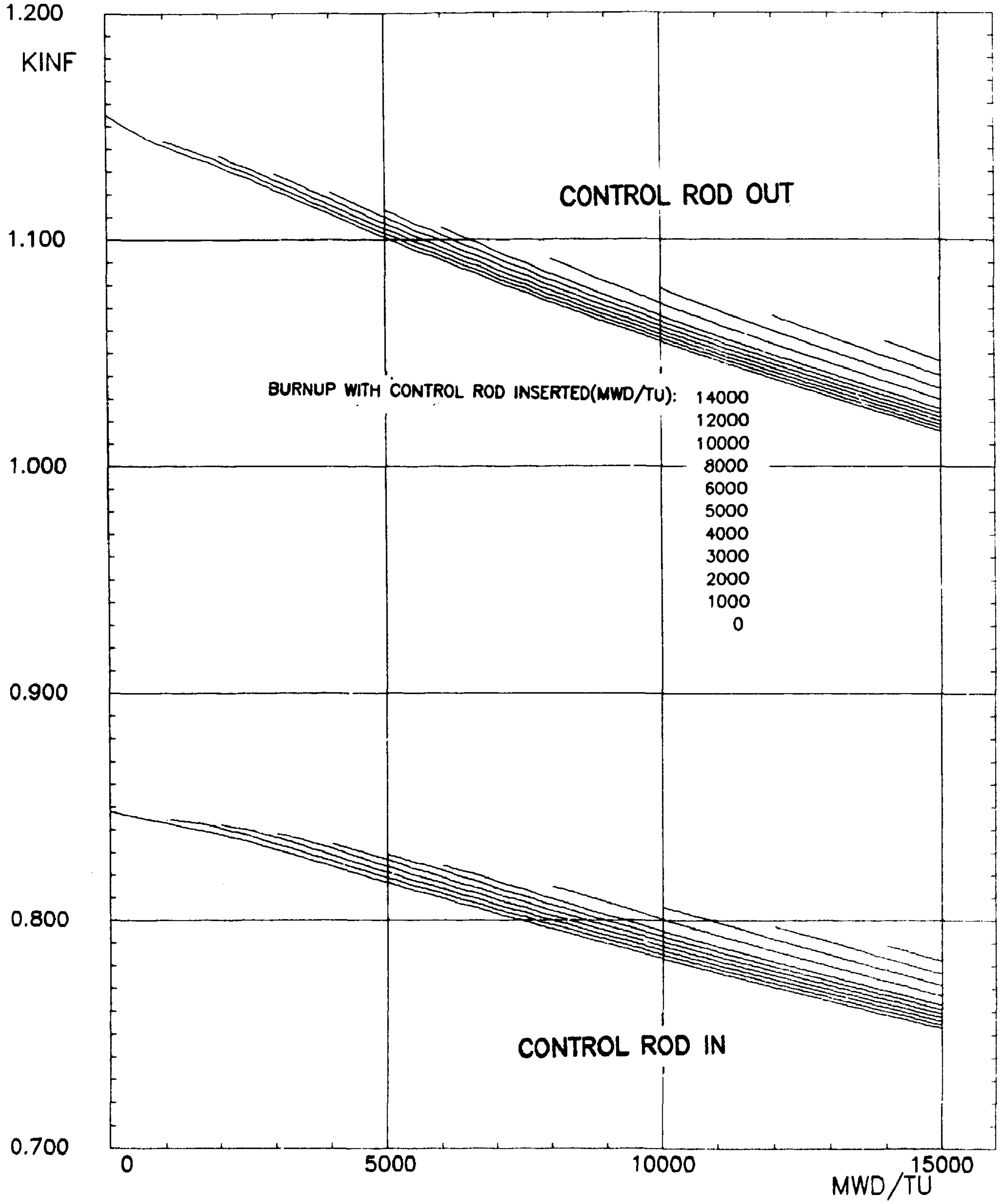


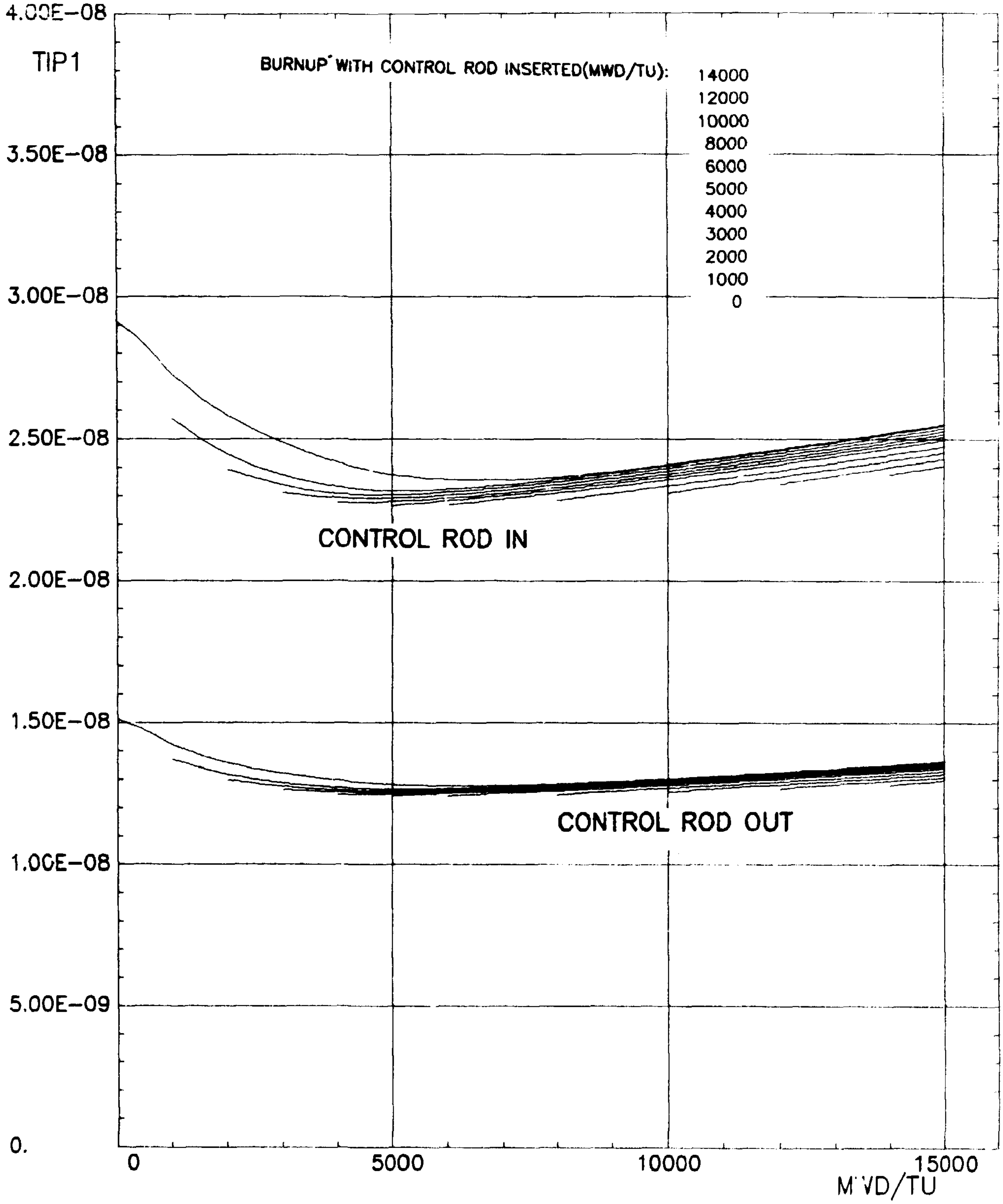
FIGURE 4.

INSTRUMENT FACTOR – FISSION CHAMBER

(NUMBER OF FISSIONS PER U235-ATOM)

PARAMETER IS THE BURNUP, WHICH HAS TAKEN PLACE WITH THE CONTROL ROD IN

FUEL ASSEMBLY: QUAD CITIES, 3 GD PINS, 50% VOID



Title and author(s)

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Descriptors - INIS:

BURNUP; BWR TYPE REACTORS; C CODES; COMPUTERIZED SIMULATION; CONTROL ELEMENTS; FLUXMETERS; NEUTRON DIFFUSION EQUATION; NEUTRON FLUX; REACTOR CORES

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